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ABSTRACT

This paper reports on a study that investigated the alternative conceptions of students in a biology and geology teacher education course regarding plant nutrition. Data were collected from first year and final year students using a questionnaire that had both multiple choice and descriptive items. Findings indicate common features related to the alternative conceptions of the two groups of students such as their anthropomorphic nature, their observable characteristics, the tendency of those questioned to move from specific meanings to others, and their particular character. Tentative inferences about the possible origins of the alternative conceptions are also identified. Appendix includes the questionnaire. Contains 21 references. (JRH)

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1997 NARST ANNUAL MEETING

SOME CONTRIBUTIONS FOR A PEDAGOGICAL TREATMENT OF ALTERNATIVE CONCEPTIONS IN BIOLOGY:

AN EXAMPLE FROM PLANT NUTRITION

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Some Contributions for a Pedagogical Treatment of Alternative Conceptions in Biology: An Example from Plant Nutrition

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Abstract

This paper describes a field research on alternative conceptions regarding plant nutrition and based on the application of an adequate questionnaire composed of both multiple choice and descriptive items. Two groups of students, both attending a five year university Portuguese course, specially designed for biology and geology teacher education, were investigated. One of the groups corresponded to first year students while the other had to do with last year subjects, that is, with students that were having their pre-service specialised training. Some of the more relevant conclusions of the study include a few important common features related to the alternative conceptions of the two groups of students, such as their anthropomorphic nature, their observable characteristics, the tendency of those questioned to move from specific meanings to others, and their particular character. Tentative inferences about the possible origins of the alternative conceptions identified, such as the ones related to eventual failure in the teaching and learning processes, were also attempted.

1. INTRODUCTION

One of the most influent lines of research that have emerged in the past few decades in the domain of science education is related to the study of the students' personal conceptions and their impact on learning and problem-solving in school context. As John Dewey already stated (1933), *problem solving* plays a crucial role in the construction of knowledge, functioning as a stimulus and a driving force of the activity of thinking. Besides its cognitive dimension, problem solving is, in that way, in close association with the development of important metacognitive habits, attitudes and skills, reflected on the regulation, monitoring and evaluation of the processes of thinking and the types of knowledge at stake (Neto, 1995). In what science instruction is concerned, it is worth pointing out the decisive role of the pupil's reflective (metacognitive) ability, when differentiating the formal (scientific) knowledge school is presenting to him from his

spontaneous knowledge (Vygotsky, 1986) – or, in other words, from his *alternative conceptions*. A huge amount of research has, indeed, indicated that people have already developed personal and very persistent ideas about a variety of topics, before starting their formal education in science (Black and Lucas, 1993; Driver, Guesne and Tiberghien, 1985; Driver, Leach, Millar and Scott, 1996; Osborne and Freyberg, 1985; Rodrigo, Rodríguez and Marrero, 1993).

The purpose of this important field of the science education research enterprise has been to study not only the pupils' alternative conceptions, but also the ones shown by curricular projects, textbooks and by the teachers themselves. The first work undertaken in this field dates from the early 70's. From then onwards, and mainly in the 80's, the investigation of alternative conceptions became a central subject in the science pedagogical domain, having already to present a considerable number of studies dedicated to various biological topics (Bettencourt and Amaral, 1994; Giordan, 1987; Mateos Giménez, 1993; Santos, 1991; Smith and Anderson, 1984).

2. THE PROBLEM

As secondary science education teachers, carrying out the function of mentors of teacher education training for the fifth year students (student-teachers, actually) of the Biology and Geology Education Course in the University of Évora, the first two of us have been noticing for some years now that the base of scientific knowledge relative to certain biological topics, either of the pupils finishing the secondary school, or the trainee teachers, cannot, by no means, be always considered the best.

Thus, we decided to undertake a study on *alternative conceptions*, focusing especially on their implications for the future biology teacher in the transformation of his or her pedagogical specific content knowledge. In that sense, we decided to compare the alternative conceptions that could be expressed by first year students and trainee teachers of the Biology and Geology Education Course of the University of Évora. For this purpose, a subject that is consensually considered as really difficult to approach (de

Vechi and Giordan, 1996; Giordan and de Vechi, 1995) at any level of education was selected: plant nutrition, generally called photosynthesis.

Photosynthesis is, indeed, a quite complex biochemical process, which is still arousing some controversy, even at a strict scientific level. It is a process that develops in a continuous form by the interaction of various factors, and not an event resulting from a total of independent factors with no relation between them (Barrabin & Sánchez, 1996; Driver, Squires, Rusworth and Wood-Robinson, 1994; Giordan, 1987).

How can one expect that a student, fully convinced that the plants absorb their nourishment from the soil or that they are nourished in a different way, understands that they are actually nourished using some organic compounds, produced by themselves in their own cells? Can we expect that a person with some biological background, but who does not know in fact the photosynthetic process, essential for the existence of life on our planet, can appreciate and respect the local, national and world flora?

We were always surprised, on one hand, by the difficulty that a big part of the pupils of the elementary and secondary education expressed in biology, in respect to the acquisition of scientific knowledge related to the photosynthetic process/plant nutrition; and, on the other hand, the difficulty that the trainee teachers, with whom we have been working, show in transmitting the scientific knowledge relative to the above subject, in a way that might enable their pupils to achieve meaningful learning. It is actually very frequent, while previously planning the work, that the trainee teachers come to us, as their mentors, in order to clarify doubts that are sometimes really surprising for us, given that their nature seems to reveal true ignorance regarding the details of the photosynthetic process or confusion sometimes difficult to imagine and understand, coming from people that received scientific training in biology during their formal education at the level of elementary, secondary and higher education.

In order to achieve our research goal, the following general objectives were considered:

- To identify the main alternative conceptions about plant nutrition expressed by the first year biology/geology students and biology/geology student-teachers.

- To compare them with the conceptions reported on the literature.
- To discuss some possible causes for the alternative conceptions expressed by the two groups questioned.

The study should be described as exploratory, since its main objective, and according to Gil (1991), was "to provide a deeper familiarity with the problem, in a way as to make it more explicit or to construct hypotheses" (p. 45), in what the expression of scientific and alternative conceptions by a certain sample is concerned.

Thus, although the planning of the exploratory research is quite flexible, in our case we think that the investigation will be able to assume the form of a case study, characterised, to quote Gil (1991), "by the profound and exhaustive study of one or few objects, in a way that allows its broad and detailed knowledge" (p. 58).

3. METHODOLOGY AND THE INSTRUMENT

In order to achieve the objectives proposed, we turned to the methodology of inquiry by questionnaire (in annex), adapting it from the work of Bettencourt and Amaral (1994). The questionnaire is composed by two different parts: in the first part, it is required from the subjects to elaborate a sentence relating two words connected to the photosynthetic process, which are provided with the aim to explain the way how the plants are nourished; the second part is composed by multiple choice answers, and the people questioned are asked, depending on the case, to choose only one or more than one option. In every question, the interviewees have the possibility to indicate another option, different from the ones they are presented.

With the purpose of testing and, eventually, bring some adjustments to the instrument prepared, a pilot rehearsal was carried out. The pilot sample was composed of fourth year Biology and Geology Education Students also attending the University of Évora. This sample was selected taking into consideration the easy access to it, the great probability of obtaining the data we needed and particularly because it involved a group that, in the short term, would be in a school doing its training year in teacher education,

maintaining, however, a straight educational relationship with the University. A sample like this seemed appropriate, since, besides the reasons already mentioned, it presented characteristics very close to those of the sample we were going to work with in our investigation.

The sample properly selected for the study was finally constituted by two groups of students of the Biology and Geology Education Course, one referring to the first year students and the other to the student-teachers.

4. CONCEPTIONS IDENTIFIED: THE RESULTS

4.1. Results: Part I

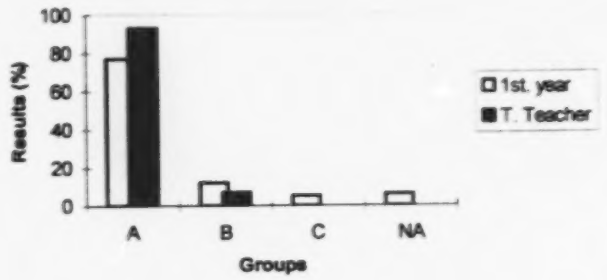
At this point, the groups of conceptions identified in the sentences written by the interviewees will be presented, referring to the relation between terms, and the respective distribution in percentage of those questioned, according to the different groups or categories of conceptions. The figures will go along with the comments we consider appropriate, regarding the conceptions identified.

The main objective of the work was to try to identify, whenever possible, *the* alternative conceptions referring to the photosynthetic process/plant nutrition; for this reason, other conceptions that went in a certain way beyond the scope of our exploratory study were not dealt with, since they constitute in themselves the focus of another investigation we intend to develop in the near future.

4.1.1. *Photosynthesis / Nourishment*

As Figure 1 shows, the majority of the answers given by the first year students and the trainee teachers reveal the correct scientific conception on this aspect. In fact, 77 % of the first year students and 93 % of the trainee teachers consider that photosynthesis is the process through which the plant obtains nourishment (Group A), as we can read in two of the answers of a first year student and a trainee teacher, respectively: *"The plants*

carrying out the photosynthesis obtain the nutrients necessary for their survival."; "*Photosynthesis is the mechanism that allows the plants to produce their nourishment.*".



A - The plant obtains nourishment through photosynthesis.

B - Nutrients are necessary for photosynthesis to occur.

C - There is no relation between photosynthesis and nourishment.

NA - No answer.[1]

Figure 1 - *Groups of conceptions referring to the relation between photosynthesis and nourishment.*

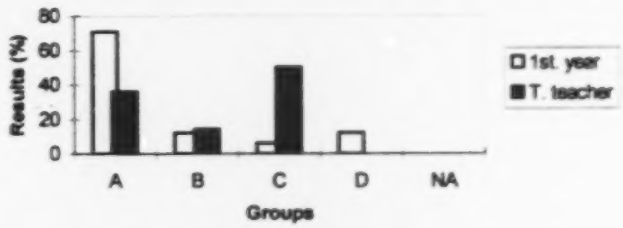
In the case of Group B, where 12 % of the first year students and 7 % of the trainee teachers are included, it seems to occur an inversion in the explanation of the photosynthetic process, as can be deduced from two answers, respectively of a first year student and a trainee teacher: "*A plant that is carrying out the process of photosynthesis has to have nourishment to be healthy.*"; "*It is through the nourishment that the plants carry out the photosynthesis.*" .

4.1.2. *Nourishment / Energy*

As Figure 2 denotes, the majority of the first year students (71 %) present the correct conception when identifying nourishment as the source of energy (Group A); 36 % of the trainee teachers were also put into this group. With a slightly bigger occurrence among the trainee teachers, there appears, however, another vision of the process: the necessity for the plant to have chemical energy in order to obtain its nourishment (idea related to

[1] The abbreviation NA appears with the same meaning in all the graphics presented.

Group B). In the scope of this study, this conception can be considered correct, if we accept that TPA is necessary in order to produce organic compounds.



A - Nourishment is identified as the source of chemical energy.

B - The plant needs chemical energy in order to obtain nourishment.

C - There is no association between chemical energy and nourishment.

D - Energy is the nourishment of the plants.

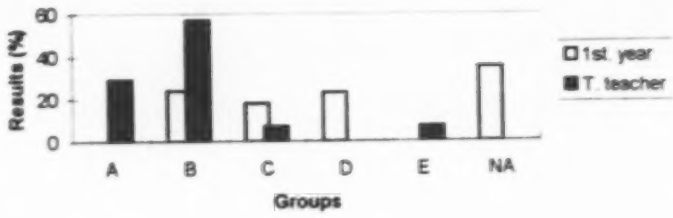
Figure 2 - *Groups of conceptions referring to the relation between nourishment and energy.*

Group C includes sentences that do not establish an association between chemical energy and nourishment. Although the first year students are distributed by all the categories of conceptions, in this group there appears a higher percentage of answers given by the trainee teachers (50 %). The conceptions typified by Group D were expressed only by first year students. These students assume that energy is the nourishment of the plants.

4.1.3. *Water / Carbon Dioxide*

In Figure 3, Group A has to do with the scientific linking between these words, according to which the association of water and carbon dioxide leads to the production of nutrients. This conception was only expressed by 29% of the trainee teachers. Groups B and C include conceptions that, although very vague, could also be considered correct.

Group C is related to answers in which the subjects questioned showed that they knew that the plant absorbs water and carbon dioxide; 18% of answers given by first year students and 7% by trainee teachers were classified in it.



A - Water and carbon dioxide are binding in order to produce nutrients for the plants.

B - Water and carbon dioxide are necessary for photosynthesis to occur.

C - The plant absorbs water and carbon dioxide.

D - There is a confusion between photosynthesis and respiration.

E - Water is formed from carbon dioxide.

Figure 3 - *Groups of conceptions referring to the relation between water and carbon dioxide.*

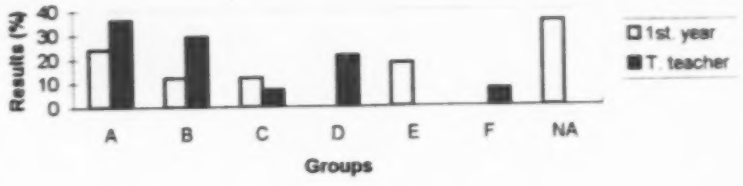
Group D, representing only 23% of the first year students, shows an implicit confusion between photosynthesis and respiration. It should be noticed that the people questioned should relate the two words in a way that could explain the plant nutrition and what they finally did was to confuse the agents entering in photosynthesis with the products resulting from respiration. An analysis of the sentence "*The products of photosynthesis are water and carbon dioxide.*" can confirm this. Group E includes only one trainee teacher (7%) and reveals confused ideas regarding the origin of water and carbon dioxide in the process of photosynthesis.

4.1.4. *Water / Oxygen*

Analysing Figure 4, it can be concluded that also for this pair of words various categories that include correct answers were found corresponding to the groups A,B,C and D. In Group A, the conception "*The water enters the plant while oxygen is released.*" was dominant: 24% of first year students and 36% of trainee teachers .

In what Group B is concerned, sentences that refer to water and oxygen as products of photosynthesis were found, having more trainee teachers (29%) than first year students (12%) expressed this idea. Group C includes 12% of the first year students and 7% of

the trainee teachers; that is, some of those questioned only accept that water and oxygen are important, not adding anything else.



A - Water enters and oxygen is released.

B - Water and oxygen are the products of photosynthesis or are released by the plant.

C - The importance of water and carbon dioxide is recognised, but nothing else is added.

D - The oxygen released comes from the molecule of water.

E - The oxygen enters the plant because it is held in the molecule of water.

F - There is some confusion between photosynthesis and respiration.

Figure 4 - *Groups of conceptions referring to the relation between water and oxygen.*

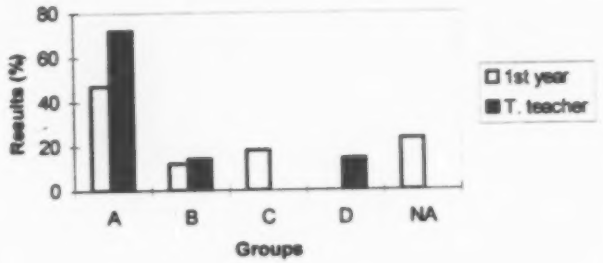
In Group D, answers only from trainee teachers were provided, in which they consider that the oxygen released during photosynthesis comes from the division of the molecules of the water absorbed. Group E, including only first year students (18%), presents the conception that the oxygen enters the plant because it is held in the molecule of water. The conception included in Group F was expressed by one of the trainee teachers.

4.1.5. *Oxygen/Carbon Dioxide*

In Figure 5, Group A has to do with the correct conception, on the scientific point of view. A great part of the first year students (47%) and the great majority of the trainee teachers (74%) are included here. Two examples could be: *"Oxygen and carbon dioxide are two gases used in photosynthesis, O_2 is released and CO_2 consumed."* and *"The plants absorb carbon dioxide and release oxygen."*.

Group B embodies answers that seem to indicate a certain ignorance regarding the subject. This ignorance, revealed in 12 % of the first year students and 14 % of the trainee teachers, can be considered incomprehensible and preoccupying. It poses the

question: *what do the subjects questioned really know about photosynthesis, if they did not manage to construct a correct sentence that relates oxygen and carbon dioxide during the photosynthetic process?* The following phrases illustrate this idea: *"it is the gaseous exchange between the environment and the plant after the combustion of some reagents"*; *"oxygen and carbon dioxide are chemical elements included in the photosynthetic process"*.



A - During photosynthesis, the plant absorbs carbon dioxide and releases oxygen.

B - Oxygen and carbon dioxide are important.

C - Oxygen comes from carbon dioxide.

D - There is some confusion between photosynthesis and respiration.

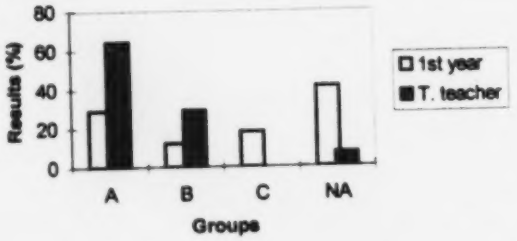
Figure 5 - *Groups of conceptions referring to the relation between oxygen and carbon dioxide.*

Group C, whose members adopted the alternative conception which attributes the provenance of oxygen to carbon dioxide, includes 18 % of the first year students; an example is: *"The plant absorbs carbon dioxide and through the photosynthesis transforms it in oxygen and releases it."*.

Group D typifies an alternative conception we have already reflected upon and which shows the existing confusion between photosynthesis and respiration. In this group, only answers given by trainee teachers were registered. The one that follows is only one example: *"Oxygen is used by the cells during the mobilisation of the energy of the nutrients, after which CO_2 is released."*.

4.1.6. *Energy / Glucids (Sugars or organic compounds)*

As it can be inferred from Figure 6, the statements constructed relating these two words are grouped in a way very similar to the ones relating the second pair of words (nourishment/energy), now with one less group.



A - The organic compounds are sources of chemical energy.

B - Chemical energy is necessary for the production of chemical compounds.

C - There is no relation, students do not know of any.

Figure 6 - *Groups of conceptions referring to the relation between energy and glucids (sugars or chemical compounds).*

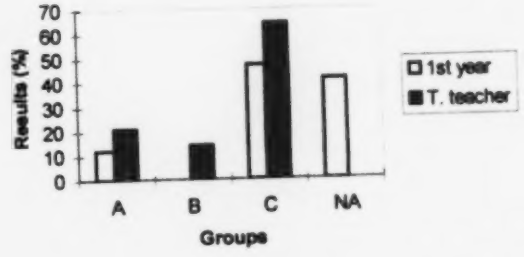
The distribution of the answers in these groups is also the one we had expected: the trainee teachers are divided between those who consider that the chemical compounds are a source of chemical energy (64 % in Group A) and those who invert the question (29 % in Group B). Also, the first year students gave answers that can fit Groups A (29 %) and B (12 %).

Among the first year students a certain difficulty in relating the words energy and glucids (sugars or organic compounds) was detected, as can be inferred by the percentage of students whose phrases fit Group C (18 %) and by the high percentage of first year students that did not answer (41 %).

4.1.7. *Mineral Salts / Nourishment*

It is evident from Figure 7 that for some first year students (12 %) and trainee teachers (21 %), the mineral salts are important (Group A). This conception can be considered

correct, although very vague. The phrases *"another nutrient necessary for the photosynthesis"*, *"in order to compose organic material the plants need mineral salts that they get from the soil"*, written by one of the first year students and one of the trainee teachers, respectively, can provide a better explanation.



A - The mineral salts are important.

B - The nourishment contains mineral salts.

C - The mineral salts are the nourishment of the plants.

Figure 7 - *Groups of conceptions referring to the relation between mineral salts and nourishment.*

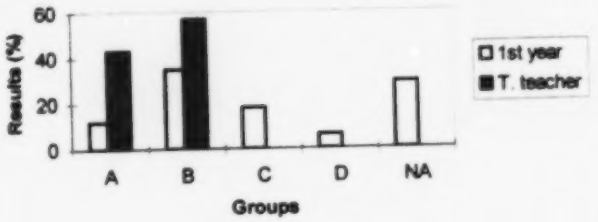
Group B also brings together answers that include correct conceptions. In this group, only answers given by trainee teachers (14 %) were found. The following sentence can illustrate the general conception attributed to this group: *"The mineral salts participate in the composition of nourishment."*.

In Group C, it seems also obvious that a great number of the first year students (47 %) and trainee teachers (64 %) have the alternative conception that the mineral salts are the nourishment of the plants. In this group, statements like *"The mineral salts will serve as nourishment for the plant."* (the case of a first year student) and *"The mineral salts are one of the nutrients of the plant, in other words, the plants need them in order to develop."* (the case of a trainee teacher) were categorised.

4.1.8. *Light / Chlorophyll*

Observing Figure 8, it can be verified that in Group A, corresponding to the explanation that is closer to the scientific conception, some first year students (12 %) and trainee

teachers (43 %) did not "fail" to attribute a certain voluntary attitude to the chlorophyll that "*uses*" the light in order to carry out the photosynthesis, as it is partly shown by the phrase "*the chlorophyll uses the solar light in order to carry out the photosynthesis.*



A - The plants with chlorophyll use light in order to carry out the photosynthesis.

B - Chlorophyll is responsible for absorbing the light needed.

C - The light forms the chlorophyll.

D - Chlorophyll and light are not related.

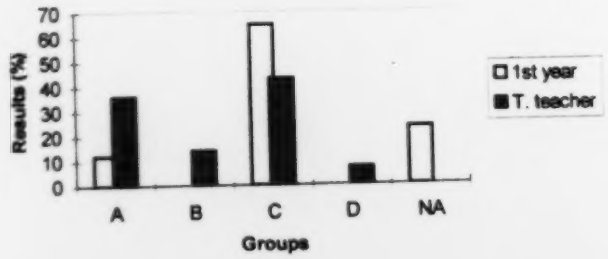
Figure 8 - *Groups of conceptions referring to the relation between light and chlorophyll.*

In Group B, a high percentage of first year students (35 %) and trainee teachers (57 %) that express the correct conception was found, recognising that the chlorophyll is responsible for absorbing light.

Group C brings together answers given by first year students (18 %) who believe that the light forms the chlorophyll. Although it is a correct conception, it does not relate light and chlorophyll, in a way to explain the plant nutrition, as they were asked. The following sentence may illustrate this point: "*The light is very important for the plants, in order to be able to produce chlorophyll.*".

4.1.9. *Soil / Roots*

The only group that displayed the correct conception (Figure 9) was Group A ("*The roots absorb mineral salts and water from the soil.*"). In this group, 12 % of the answers were given by first year students and 36 % by trainee teachers . They were answers like the following: "*The roots get the water and mineral salts from the soil.*"; "*Through the roots the plant absorbs water and mineral salts from the soil.*".



A - The roots absorb mineral salts and water from the soil.

B - The roots capture mineral salts and water from the soil.

C - The roots absorb the nutrients from the soil.

D - The roots are in the soil.

Figure 9 - *Groups of conceptions referring to the relation between the soil and the roots.*

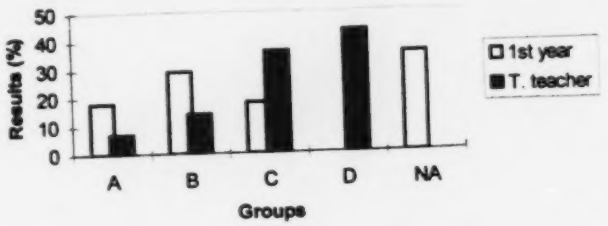
The conceptions classified in Group B, although correct on the scientific point of view, appear to be incomplete; 14 % of the answers of the trainee teachers were found in this group, as it is the case of the one that follows: "*In the soil there exist mineral salts that are absorbed by the roots.*".

In Group C, it appears to be revealed an alternative conception that was also expressed in other previous items; 65 % of the answers of first year students and 43 % of the answers of trainee teachers were here included. The following sentences might give an idea of what we just mentioned: "*The soil provides nourishment for the plant that is absorbed by the roots.*"; "*The plants get the nutrients they need from the soil through the roots.*".

4.1.10. *Air / Leaves*

In Figure 10, Group A corresponds to the scientific conception and includes 18 % and 7 . % of the answers given, respectively, by first year students and trainee teachers.

Group B embodies 29 % of the answers of the first year students and 14 % of the answers of the trainee teachers. This group illustrates the following alternative conception: "*The leaves are only related to respiration, as if they were lungs.*".



A - Through the leaves carbon dioxide enters and oxygen is released.

B - The leaves are related to the respiration.

C - There is no relation between them.

D -The role of the air and the leaves was recognised, but nothing else was added.

Figure 10 - *Groups of conceptions referring to the relation between the air and the leaves.*

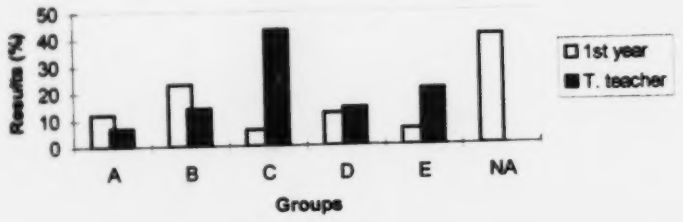
Regarding Group D, where 43 % of the answers of trainee teachers are included, it seems that a certain importance is attributed to the air and the leaves. Nevertheless, the terms are not related in a way to explain how the plants are nourished.

4.1.11. *Roots / Leaves*

As it is shown in Figure 11, Group A, corresponding to the scientific point of view, includes 12 % of the answers of the first year students and 7% of the trainee teachers.

Group B illustrates one of the alternative conceptions on plant nutrition that kept being expressed in this study, here displayed by 23 % and 14 % of the answers given by the first year students and by the trainee teachers, respectively.

Group C brings together the answers that, although attributing importance to the roots and leaves, do not relate the two words in a way to explain how the plants are nourished. In this group, 6 % of the answers of first year students and 43 % of the answers given by trainee teachers were registered. Group E illustrates one of the alternative conceptions that has also kept coming up, concerning the way in which the plants are nourished.



A - The roots capture substances from the soil and the leaves capture light.

B - The roots absorb the nourishment for the leaves.

C - The leaves and the roots are important parts of the plants.

D - Do not relate.

E - Both the leaves and the roots capture nutrients.

Figure 11 - *Groups of conceptions referring to the relation between the roots and the leaves.*

4.2. Results: Part II

As it was referred for Part I of the questionnaire, also in this part only conceptions concerning the subject of the photosynthetic process/plant nutrition were taken into consideration.

4.2.1. *Photosynthesis is ...*

As it can be observed in Figure 12, 65% of the first year students and 86% of the trainee teachers selected the option that was presenting the scientifically correct conception, regarding photosynthesis: "*Photosynthesis is the process by which the plant obtains nourishment.*".

The answer "*Photosynthesis is the process that allows the plant to breath.*" was selected by 23% of the first year students and 7% of the trainee teachers. In these results there seems to be expressed an alternative conception that, in Part I of the questionnaire, was revealed among first year students (regarding the relation of the terms water / carbon dioxide and air / leaves) and among trainee teachers (regarding the relation of the terms

water / oxygen / carbon dioxide and air / leaves). This fact seems to confirm the existing confusion between photosynthesis and respiration.

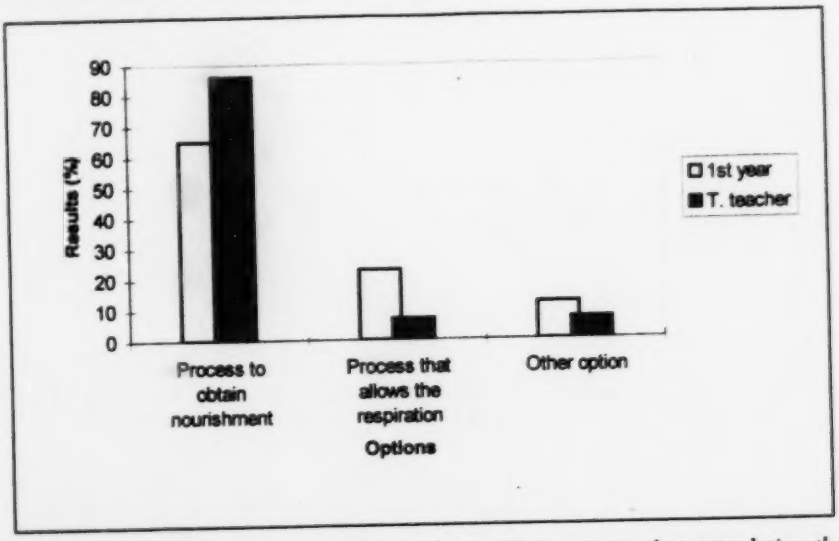


Figure 12 - *Distribution of those questioned according to their options when completing the sentence "Photosynthesis is..."*

It is worth mentioning that two of the first year students chose the options: "*Photosynthesis is the process that allows the plant to obtain energy.*" and "*Photosynthesis is a process by which the plant produces energy.*". One of the trainee teachers wrote "*Photosynthesis is the process by which the plant obtains nourishment and oxygen is produced.*". These answers seem to agree with the scientific point of view; meanwhile, those given by first year students could make us think that these students do not associate nourishment and energy.

4.2.2. *The source of energy that allows the plants to grow ...*

In this case (Figure 13), it is possible to note that 65% of the first year students and 50% of the trainee teachers believe that the plant grows due to energy deriving from light. We cannot say that this statement is not correct. However, as the question asked which is the source directly responsible for the growing of the plants, the only answer that could be accepted was the one that concerned the energy coming from the nutrients the

produced by the plants, an answer given by 18% of the first year students and 36% of the trainee teachers.

Analysing the figure in question, it seems possible to draw the conclusion that 18% of the first year students and 14% of the trainee teachers chose to answer *"The source of energy that allows the plants to grow are the substances they absorb."*, that could indicate that for these interviewees the energy for the plants to grow comes from nutrients captured from outside.

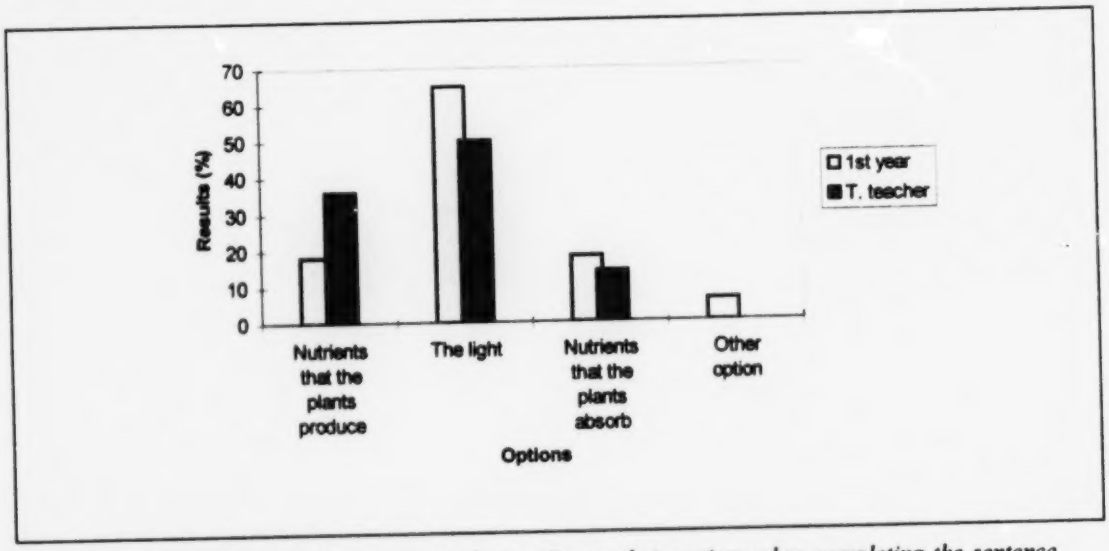


Figure 13 - *Distribution of those questioned according to their options when completing the sentence "The energy that allows the plants to grow..."*

4.2.3. *The plant is nourished ...*

Figure 14 shows that 35% of the first year students and 71% of the trainee teachers considered correctly that *"The plant is nourished by producing nutrients."*.

On the other hand, 65% of the first year students and 21% of the trainee teachers selected the option *"The plant is nourished absorbing nutrients through the roots."*, an idea that has already been expressed in the first part of the questionnaire. A small percentage of first year students (6%) and trainee teachers (7%), that consider the plant to be nourished absorbing light, was also registered.

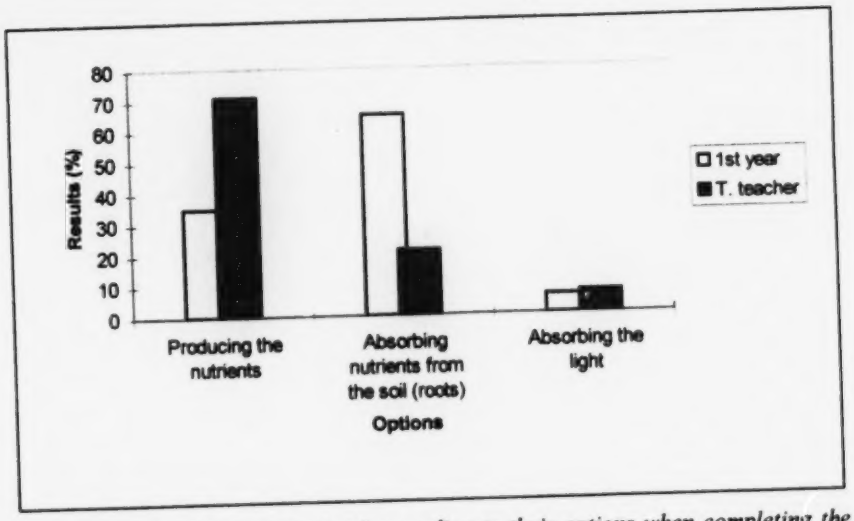


Figure 14 - *Distribution of those questioned according to their options when completing the sentence "The plant is nourished..."*

One of the first year students selected two options: the second, *"The plant is nourished by absorbing nutrients from the soil with the roots."*, and the third, *"The plant is nourished by absorbing light."*. It seems obvious that for this student the plant is nourished capturing what it needs from the exterior.

4.2.4. *The nourishment of the plant ...*

As it can be inferred from Figure 15, 65% of the answers of the first year students and 64% of the answers of the trainee teachers consider that *"The nourishment of the plant are some organic compounds."*. This is the option that agrees with the scientific conception. Regarding the option *"The nourishment of the plant are some mineral salts."*, it was selected by 76% of first year students and 64 % of trainee teachers, alternative conception already displayed before.

On the other hand, 35% and 64% of first year students and trainee teachers, respectively, selected the option *"The nourishment of the plant is the water."*, as well as 23% and 29% of them selected the option *"The nourishment of the plant is the carbon dioxide."*. Relatively to the option *"it is the light"*, 18% and 7% of the answers of first year

students and trainee teachers were respectively registered. Only one first year student and one trainee teacher chose the option "*The nourishment of the plant is the soil.*".

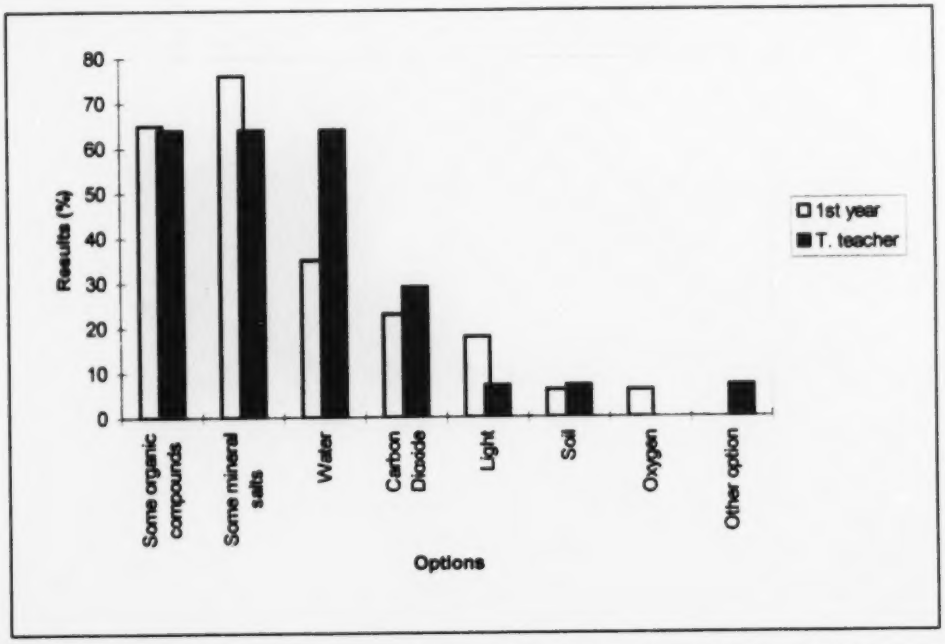


Figure 15 - *Distribution of those questioned according to their options when completing the sentence "The nourishment of the plant..."*

It should be noticed that only two first year students and only two trainee teachers chose the correct answer: "*The nourishment of the plant are some organic compounds.*". This evidence appears to confirm that the majority of those questioned consider various substances to be the nourishment of the plant.

5. MAIN ALTERNATIVE CONCEPTIONS IDENTIFIED

A summary of the main alternative conceptions identified, regarding plant nutrition, is now presented in Table 1. The following symbols were adopted: the symbol "+" means that at least one of the interviewees expressed a certain alternative conception; the symbol "++" means that a certain alternative conception appeared to be much more common in one of the interviewees' groups than in the other; the symbol "-" means that a certain alternative conception was not expressed by the group. These alternative

conceptions were considered as having punctual nature, since in their majority they have to do only with particular aspects, parts of a vaster process that Plant Nutrition is.

Table 1

Summary of the Main Alternative Conceptions, Regarding Plant Nutrition, Identified Among First Year Students and Trainee Teachers.

MAIN PUNCTUAL ALTERNATIVE CONCEPTIONS	1ST YEAR STUDENTS	TRAINEE TEACHERS
Photosynthesis is the process that allows the plant to breath.	++	+
There is some confusion between photosynthesis and respiration.	+	+
Nutrients are necessary for photosynthesis to occur.	+	+
No association between chlorophyll and light in the production of nourishment is established.	+	-
The source of energy that allows the plants to grow are the synthesised nutrients[2] together with the sunlight.	+	-
There is no association between chemical energy and glucids.	+	-
The source of energy that allows the plants to grow is the light.	++	+
The energy is the nourishment of the plants.	+	-
The source of energy that allows the plants to grow are the nutrients they absorb.	+	+
The nutrients of the plants are various.	+	+
The plant is nourished absorbing light.	++	+
The nourishment of the plants is the water absorbed.	+	+
The nourishment of the plants is the carbon dioxide.	+	+
The nourishment of the plants is the oxygen.	+	-
The nourishment of the plants is the soil.	+	+
The nourishment of the plants are the mineral salts.	+	+

(cont.)

[2] The source of energy that allows the plants to grow is in fact the organic compounds synthesised by the plant, being this a scientific conception. However, from the moment that the interviewees associate to the nutrients synthesised, another compounds or factors, that conception has to be considered alternative. This explains why we included the nutrients synthesised in the sentence that illustrates an alternative conception.

(cont.)

MAIN PUNCTUAL ALTERNATIVE CONCEPTIONS	1ST YEAR STUDENTS	TRAINEE TEACHERS
The nutrients of the plants are, among others, light and the organic compounds[3].	+	+
Both the leaves and the roots capture nutrients.	+	++
The nourishment is absorbed from the soil by the roots .	++	+
The nourishment absorbed by the roots goes to the leaves.	++	+
The leaves are related to respiration.	++	+
Water is formed from carbon dioxide.	-	+
The oxygen comes from carbon dioxide.	+	-
The oxygen enters the plant because it is contained in the water	+	-

Analysing Table 1, it can be noticed that in the study undertaken the trainee teachers, with the exception of seven, expressed, in general, alternative conceptions quite identical to the ones expressed by first year students. The only alternative conception that the first year students do not express is the one related to the provenance of water in the photosynthetic process.

The alternative conceptions expressed by first year students have the following aspects: no association is established between chlorophyll and light in the production of nourishment for the plants; the source of energy that allows the plants to grow are the composed nutrients together with the sunlight; no association is made between chemical energy and glucids; energy and the oxygen are the nutrients of the plants; the photosynthetic oxygen comes from the molecules of carbon dioxide; the oxygen enters the plant because it is contained in the molecule of water.

[3] The organic compounds are in fact the nourishment of the plants, being this a scientific conception. However, since next to the organic compounds the interviewees place other nutrients, this conception becomes alternative. This justifies why the organic compounds were included in the text, illustrating an alternative conception.

In the trainee teachers' group, on the other hand, an alternative conception revealed only by them was found, according to which in the photosynthetic process water is formed from carbon dioxide. Also in the trainee teachers' group, it seems to be more obvious than in the first year students' group the idea that both the leaves and the roots are responsible for the capturing of nutrients for the plant.

On the contrary, in the first year students' group there seems to be more common the alternative conception according to which photosynthesis is the process that allows the plant to breath, the source of energy that allows the plants to grow is light, the plant is nourished by absorbing light, the nourishment of the plant is absorbed from the soil by the roots, the nourishment absorbed by the roots goes to the leaves and the leaves are related to the respiration.

We should also point out the alternative conceptions expressed equally by first year students and trainee teachers. There seems to be a confusion between photosynthesis and respiration, the fact that the nutrients are necessary for the photosynthesis, the source of energy that allows the plants to grow are the nutrients they absorb, the nutrients of the plants are various, the nourishment of the plants is the water, the carbon dioxide, the soil, mineral salts, the light and the organic compounds.

6. CONCLUSION AND EDUCATIONAL IMPLICATIONS

Summing up, it is possible to conclude that, in a general way, the alternative conceptions expressed by the first year students' group seemed to be different in some cases, but quite identical in others, to those expressed by trainee teachers. More than the differences, though, we feel that we should concentrate on the common features between the alternative conceptions identified in the two groups, as for example their anthropomorphic nature, their observable character and their origin in the interviewees' tendency to move from one meaning to the other.

There are, then, various and, in our opinion, relevant didactic implications of this study for the training of the future biology teacher in what should be his "most noble

educational function" as a competent professional: by reflecting on his knowledge and his practice (Schön, 1987), try to help students guide and regulate their own learning, that is, enable them to "learn to think". Only under those circumstances this teacher might be really able to contribute to his students' full development, development that, being cognitive, metacognitive and emotional is, in a word, cultural, in the sense that Whitehead (1967) was giving to the word culture:

> Culture is activity of thought, and receptiveness to beauty and humane feeling... A merely well-informed man is the most useless bore on God's earth... Education with inert ideas is not only useless: it is, above all things, harmful. (pp. 1-2)

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8. ANNEX

QUESTIONNAIRE*

The questionnaire you are presented is constituted by two parts. It intends to obtain data that will allow to carry out an investigation on the knowledge of Biology and Geology university students, relative to plant nutrition.

All information provided will be anonymous and confidential, used only for academic study purpose.

Thank you for your collaboration.

* Adapted by Adelaide Neto Vaz and Maria Helena Carola from T. Bettencourt and I. Amaral (1994). A Nutrição das Plantas. *Ensino de ciências e formação de professores - Projecto MUTARE.* Universidade de Aveiro, 3, 33-87.

PART I

In this part, try to explain, in a synthetic form, the WAY IN WHICH THE PLANTS ARE NOURISHED, relating the following words by using an appropriate, complete sentence.

1 - Photosynthesis / Nourishment

_____

_____

2 - Nourishment / Energy

_____

_____

3 - Water / Carbon Dioxide

_____

_____

4 - Water / Oxygen

_____

_____

5 - Oxygen / Carbon Dioxide

_____

_____

6 - Energy / Glucose (sugars or organic compounds)

_____

_____

7 - Mineral Salts / Nourishment

_____

_____

8 - Light / Chlorophyll

_____

_____

9 - Soil / Roots

_____

_____

10 - Air / Leaves

_____

_____

11 - Roots / leaves

_____

_____

PART II

Taking into consideration your ideas regarding PLANT NUTRITION, select the option (or options) that better completes (or complete) each one of the four unfinished statements indicated below. For this, mark with a cross (x) in the respective square(s):

. ONLY ONE option for questions number 1, 2 and 3.

. ONE OR MORE options for question number 4.

1 - Photosynthesis is...

☐ - the nourishment of the plant.
☐ - the chlorophyll existing in the green parts of the plant.
☐ - a process taking place in the plant when it has nourishment.
☐ - the process by which the plant obtains nourishment.
☐ - the process that allows the plant to breath.
☐ - other option (please indicate) _____.

2 - The source of energy that allows the plants to grow...

☐ - is the light received.
☐ - is the nourishment that the plants produce.
☐ - is the nourishment they absorb.
☐ - are the substances they release.
☐ - is other option (please indicate) _____.

3 - The plant is nourished by...

☐ - absorbing light.
☐ - absorbing the nutrients from the air through the leaves.
☐ - absorbing the nutrients from the soil through the roots.
☐ - producing its nourishment.
☐ - other option (please indicate) _____.

4 - The nourishment of the plant...

☐ - is the light received.
☐ - is the water.
☐ - is the carbon dioxide.
☐ - is the oxygen.
☐ - are some organic compounds.
☐ - is the chlorophyll.
☐ - are some mineral salts.
☐ - is the soil.
☐ - is other option (please indicate) _____.